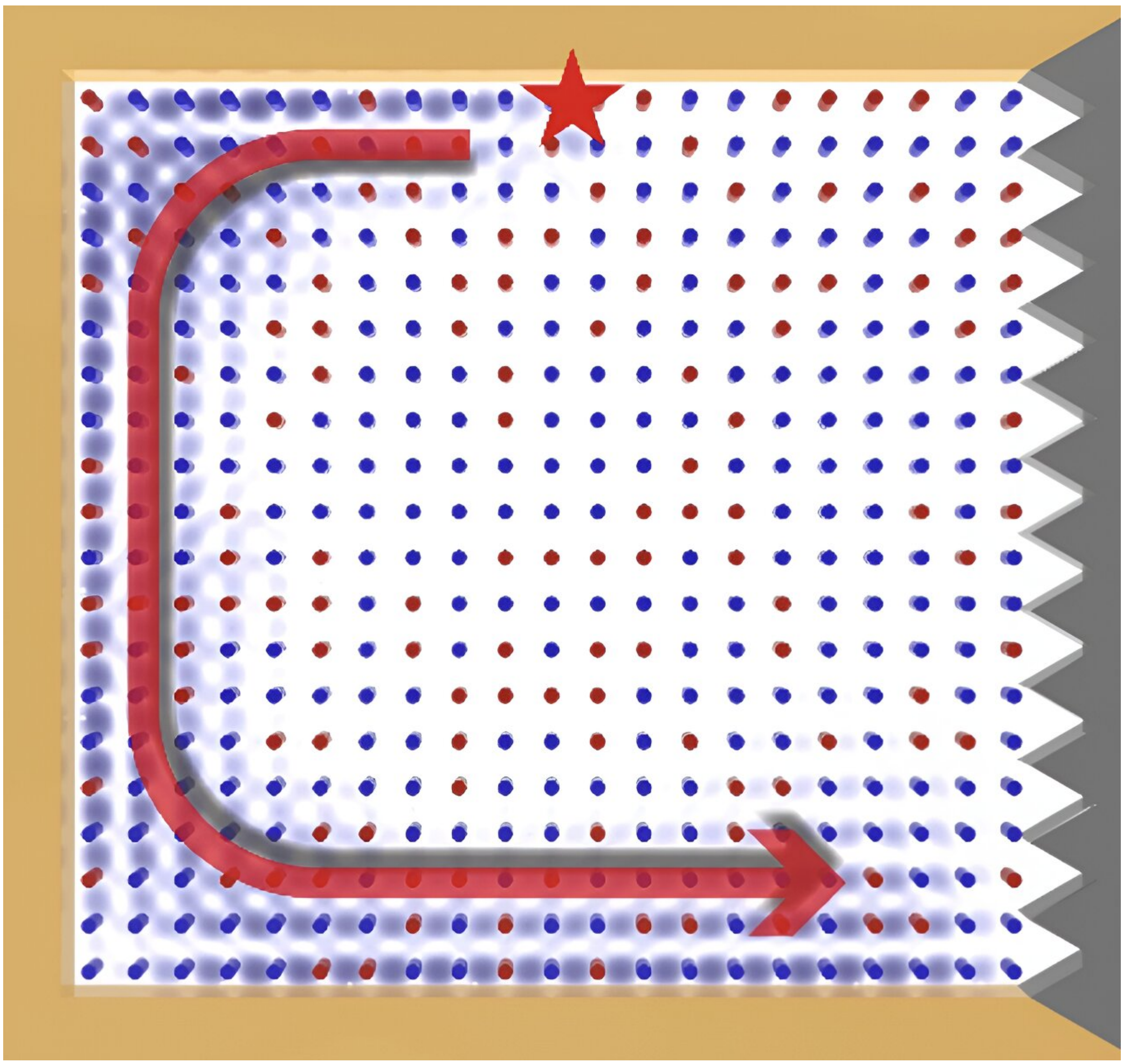
The design of a photonic alloy with topological properties

June 19 2024, by Ingrid Fadelli



Schematic diagram of a topological photonic alloy. The red star indicates the position of the line source, and the arrow indicates the direction of propagation of the chiral edge state. Credit: Qu et al.

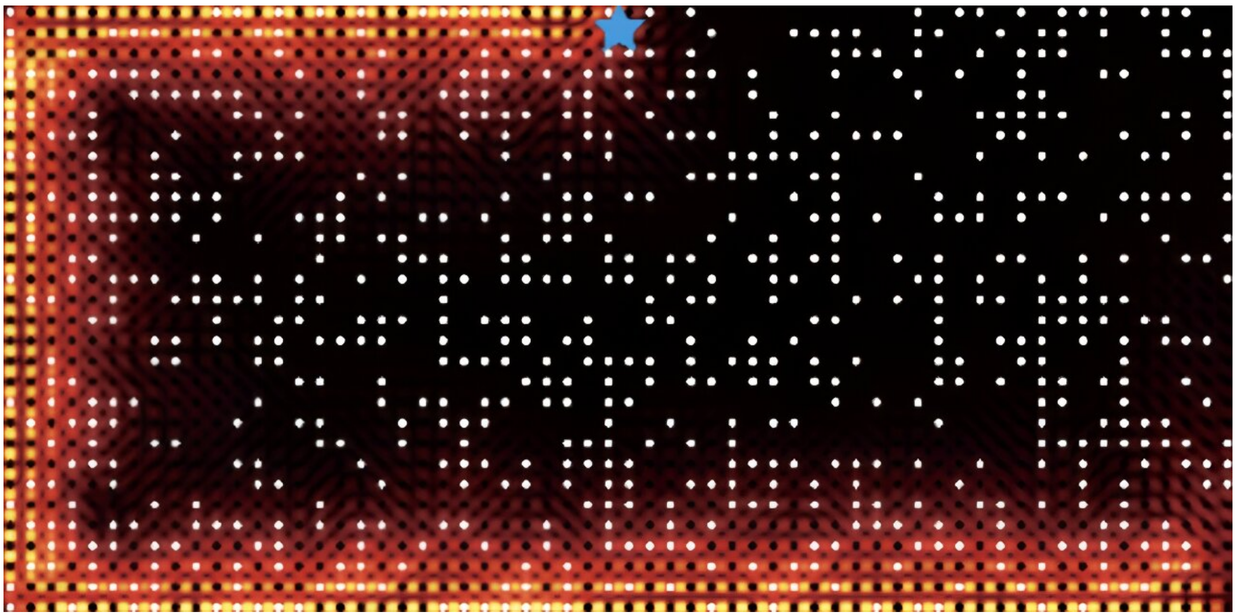
Photonic alloys, alloy-like materials combining two or more photonic crystals, are promising candidates for the development of structures that control the propagation of electromagnetic waves, also known as waveguides. Despite their potential, these materials typically reflect light back in the direction where it originated.

This phenomenon, known as light backscattering, limits the transmission of data and energy, adversely impacting the materials' performance as waveguides. Reliably reducing or preventing light backscattering in photonic alloys will thus be a key milestone towards the practical use of these materials.

Researchers at Shanxi University and the Hong Kong University of Science and Technology recently fabricated a new photonic alloy with topological properties that enables the propagation of microwaves without light backscattering. This material, introduced in *Physical Review Letters*, could pave the way for the development of new topological photonic crystals.

"Our paper introduces a new concept: the topological photonic alloy as a nonperiodic topological material," Lei Zhang, co-author of the paper, told Phys.org. "We achieved this by combining nonmagnetized and magnetized rods in a nonperiodic 2D photonic crystal configuration. This created photonic alloys that sustain chiral edge states in the microwave regime."

The primary objective of the recent study by Zhang and his colleagues was to develop a new photonic alloy exhibiting a topological edge state, drawing inspiration from the unique physical properties of alloys. The researchers created their material by randomly mixing yttrium iron garnet (YIG) rods and magnetized YIG rods comprised of substitutional or interstitial alloys.



Distribution of chiral edge states in the topological photonic alloy. White dots indicate the positions of the nonmagnetized YIG rods, black dots indicate the positions of the magnetized YIG rods, and the blue star indicates the position of the line source. Credit: Qu et al.

"In our experimental setup, a vector network analyzer is utilized to establish connections between the source and probe antennas," Zhang explained. "The source antenna is fixed at a specific position within the sample, while the probe antenna's position is varied to gather valuable information regarding the intensity and phase of the electromagnetic waves. To facilitate this process, circular holes are present in a metal plate through which both antennas are inserted."

Zhang and his colleagues used a metal cladding that served as a "topologically trivial material," with a Chern number of zero. When this cladding covers a photonic topological insulator with a Chern number of 1, a topological edge state emerges at their boundary, in alignment with the principle of bulk-edge correspondence.

"The microwave absorber in this setup is to suppress the transmission of boundary states," Zhang said. "By utilizing the absorber, we prevent the formation of a closed loop within the entire boundary state, which could interfere with the accurate characterization of nonreciprocal phenomena."

The experiments carried out by this team of researchers demonstrated that their topological photonic alloy even exhibits topological properties with a low doping concentration of magnetized rods without requiring order. This notable finding could open new possibilities for the experimental realization of topological edge states, as it suggests that chiral edge states can be produced without breaking time reversal symmetry throughout a crystal.

"In our next studies, we plan to explore multicomponent topological photonic alloy systems," Zhang added. "Multi-component systems possess a greater number of degrees of freedom, enabling the manipulation of various parameters and leading to a wider range of intriguing effects. In addition, we soon also plan to explore the possibility of realizing similar phenomena in optical frequencies and establishing the relevance of these outcomes for photonics applications would be highly intriguing."

Zhang and his colleagues hope to soon extend their recent findings to the optical domain. This would potentially open new opportunities for the manipulation of light and the development of innovative photonic devices.

More information: Tiantao Qu et al, Topological Photonic Alloy, *Physical Review Letters* (2024). DOI: 10.1103/PhysRevLett.132.223802. On *arXiv*: DOI: 10.48550/arxiv.2406.05168